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CONFERENCE REPORT: 51ST DISCUSSION FORUM ON LCA

The role of environmental life cycle thinking in long-term (energy) strategies, 51st LCA forum, Ittigen/Berne, April 25, 2013

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1 Introduction

More and more national and regional resource and energy strategies are being developed. After the Fukushima accidents, several European countries, like Germany and Switzerland, decided to phase out nuclear power and to adjust or rewrite their long-term national energy strategies. Environmental impacts are usually one element of these strategies. Life cycle assessment (LCA) is one approach that may help identify environmentally optimal energy strategies.

The Swiss and the German energy strategies were presented in this discussion forum. The role of LCA within these strategies is discussed and highlights of the most recent updates of electricity supply life cycle inventories were presented. Furthermore, sophisticated LCA approaches that deal with long-term future scenarios in a European and German context were explained, and the application of LCA on future technologies such as carbon capture and storage and hydrogen was presented.

The 51st discussion forum addressed the following questions:

– What are the key elements of the Swiss Energy Strategy 2050 and what is the role of LCA in this strategy?
– What are the main results of the updates of selected electricity supply chains (nuclear, natural gas, photovoltaic)?
– What is the role of environmental life cycle thinking in the development of national long-term strategies in Germany?
– How is or should LCA methodology be adjusted to account for future scenarios in a European context?
– How to assess energy technologies, which will only be installed in the future?

Discussion forum on LCA The discussion forum on life cycle assessment (LCA) addresses practitioners working in industry, consulting companies and administration as well as LCA scientists. Each LCA forum is dedicated to a specific topic of immediate interest related to experiences and challenges with LCA application, scientific questions in LCI and LCIA methodology development or dissemination of new scientific findings and results of relevant LCA studies.
The LCA Discussion Forum is a platform for the exchange between LCA scientists as well as for people working with LCA. Experts are invited according to the topic to present their work. Each forum offers an 'open floor' session for short presentations. The LCA forum is dedicated to people interested in the field of LCA, working in Switzerland and abroad. Its content is defined by an advisory board.

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2 The Swiss Energy Strategy 2050 and its environmental dimension

The 51st LCA forum was opened by Rolf Frischknecht (treeze Ltd.). He bridged the catastrophe in Fukushima two years ago to the present energy politics in various countries discussing nuclear phase out and the relevance of LCA in this context. The first morning session was on the energy strategy 2050 from the Swiss federal council and the potential of LCA within the energy, as well as in the building and transportation sectors. Furthermore, the environmental performance of the present electricity mix was commented on.

Beat Goldstein (BfE) presented the energy strategy 2050 (ES 2050), along with its objectives and challenges. The ES 2050 pursues security of electricity supply regarding technological, economic and environmental feasibility. He showed that enhancing energy efficiency, promoting renewable energy sources, the extension of electricity networks and enhancing international cooperation are key elements of the ES 2050. Three scenarios describe potential situations of the future energy supply. Not only economic aspects are important for prospective energy planning but also the environmental performance of the electricity production. Goldstein illustrated that LCA information is a prerequisite for the decision-making process and that LCA provides supportive

information for promoting renewable electricity production. Furthermore, LCA information is relevant for the electricity disclosure as it builds a bridge between electricity production and consumption.

Lukas Gutzwiller (BFE) focused on the demand side of the ES 2050, especially on the buildings and transportation sector. In his presentation, he showed where LCA contributed to policy making in the past and where it might contribute in the future. Gutzwiller pointed out the importance of nearly zero-energy buildings (NZEB) and their technical requirements. In his presentation, it became evident that the building envelope is crucial for NZEB. Refurbished buildings do not achieve the same energy efficiency as new buildings. Furthermore, energy self-sufficiency is more difficult to reach for large (multi-storey) buildings than for single family dwellings. Low primary energy factors for electricity are an incentive for fuel shift from fossil fuels to electric heat pumps but tend to hinder the instalment of efficient equipment (ventilation, light, etc.) and of high level insulation of the building envelope. The ES 2050 envisages an increase in the number of electric heat pumps used. The electricity mix and its environmental performance are keys factors influencing the environmental impacts of space heating provided by heat pumps. Hence, LCA results are strongly influenced by the used electricity mix and are vice versa influencing the political pathway for NZEB. He showed that there is no unified approach in European regulations regarding how to calculate primary energy when assessing energy performance of buildings.

The environmental performance of the electricity mix has a crucial role in the transportation sector too, as the share of electric vehicles is expected to increase (expectation ES 2050: one of three of all passenger cars circulating in Switzerland by 2050). The environmental performance of fuel from renewable sources is similarly important for the promotion of biofuels. Gutzwiller showed that biofuels (from various feedstocks) may have lower CO_2 emission than fossil fuels, in particular if sourced from biogenic wastes. He concluded that LCA regarding biofuels was important in the past and will remain important while shifting to second-generation biofuels and electric vehicles.

Christian Baur (PSI) presented the results of a study on the environmental performance of the Swiss electricity supply mix, commissioned by the BFE as part of the ES2050. Researchers of the PSI and treeze Ltd assessed the environmental performance of power generation and quantified the environmental burdens of current electricity supply technologies. The Swiss federal office for the environment (BAFU) approved the selection of environmental indicators proposed by the authors and used in the study.

The environmental performances of electricity from natural gas power plants, nuclear power plants, photovoltaic power plants, biogas and wood power plants as well as hydro and wind power plants were compared. The data about the natural gas supply chain and natural gas power plants, about the nuclear fuel chain and nuclear power plants as well as the silicon supply chain and photovoltaic power plants were updated. Data about other technologies (e.g. wood power plants) were not updated although it would have been due. Their study showed that natural gas-based electricity causes the highest amounts of greenhouse gas emissions per kilowatt hour electricity, nuclear electricity causes the highest amounts of nuclear waste and requires the highest amounts of primary energy, photovoltaic electricity shows the highest resource intensity (especially metals) and wood-based electricity emits the largest amounts of respiratory inorganics. Furthermore, he explained that different countries produce photovoltaic wafers with different environmental efficiencies. Wafers produced in China cause 70 % more greenhouse gases than the same wafers being produced in Europe or the USA. The environmental impacts of uranium mining also vary largely from country to country. Due to the lack of information, global supply averages are used to model the nuclear fuel supply in Switzerland.

He concluded that hydro and wind power plants cause the lowest environmental impacts. Air pollution may be a challenge for biomass power production in case of less efficient flue gas treatment systems. Electricity from natural gas power plants contributes distinctly more to climate change than electricity from renewables or nuclear power plants do. Finally, Bauer showed that the mineral resource demand for photovoltaic electricity is significantly higher than for electricity from other technologies and hence future recycling of the photovoltaic modules and wafers becomes important.

3 European energy strategies and the role of LCA

Martin Pehnt (IFEU) presented his thoughts and experiences in long-term policy making and the role of LCA within the German energy transformation. He explained the importance of the 'Energiewende' for Germany and that it is not just a simple plan to reduce nuclear power but a complex system in which renewable energy sources and nuclear power plants are only rack wheels. In the long run (2050), Germany aspires to reach an energy mix with 80 % renewable energy sources and a reduction in the overall energy consumption of 50 %; however, the overall electricity demand is ever increasing (heat pumps, electric cars and other applications). Furthermore, the heat demand of buildings has to be reduced by 80 %. The challenges regarding LCA are given by the infrastructure (lock-in effects, low rate of refurbishment) and the long-time character of the planning and storage requirements. He claimed that currently LCA plays no role with respect to the Energiewende, except for biomass. In practical public policies, LCA is hardly mentioned.

As an example, he explained that the German standard for the construction of new buildings relies on the primary energy demand and the transmission losses during operation, but the energy demand for construction and demolition is disregarded. In addition, only weak requirements apply for refurbished buildings. He emphasized that in the long run the fluctuations in the energy demand will increase and showed that some renewable energy sources (wind, PV) provide electricity only seasonally, but in a complementary manner.

Pehnt concluded that LCA is a valuable instrument for agenda setting in politics and that it helps fight prejudices regarding environmental benefits of political decisions. With respect to agenda setting, the effectiveness of LCA is currently underestimated.

Gjalt Huppes (CML) lectured on scope-dependent LCA outcomes, with examples on climate policy instruments. He brought up the question whether the world would become 'better' by making the right choice at hand and how such a question can be addressed with the help of LCA. By basing decisions on micro-level as an approximation on macro-level one could estimate effects on the macro-level. Technology choices are influenced by public policies, institutions, culture and the economics. However, effects mechanisms of these four parameters are only analysed partially in current LCAs. The choice on technologies may have large effects on the environment. These can be assessed limiting the scope to direct effects or to broaden the scope including indirect effects, consequential LCA, rebound effects or to go for an LC sustainability analysis or even outside LCA with a cost–benefit analysis or an integrated assessment. Huppes reasoned that technology choices depend on policy instruments and vice versa. At the examples of a coal-fired power plant and of biofuels replacing gasoline, he showed that a range of policy instruments have an effect on the performance of the power plant and the fuel system, respectively, and will lead to a direct improvement. However, the overall effects on the environment can be positive, zero or even negative. A change on various levels influences the system. These system levels are not working in a coordinated way and no systematic approach is available so far. He concluded that a systematic view on consequences of decisions is not yet properly transformed to defining the scope of the LCA properly, in particular if applied on large-scale public policy measures.

The last presentation of the morning sessions was given by Peter Viebahn (Wupppertal Institute). He presented results from a dynamic LCA on the heat sector in Germany, modelling the impacts of climate protection strategies on resource consumption and emissions. He explained that the present energy system is based on non-sustainable and non-future-oriented resource depletion. Resource efficiency strategies are intensively discussed internationally and nationally. In his study, he followed the question, how resource efficiency is modelled best and if there are trade-offs between resource efficiency and socio-political targets such as climate protection. In his study, he applied a life cycle approach on energy scenario analyses. The scenarios are based on the existing energy scenarios from the BMU 'Lead Study 2008'. For the human need of 'warm living area', specific resource efficiency requirements were derived and modelled with the technology model HEAT. The environmental impacts were dynamically assessed with LCA using a consequential approach. They used material input per service unit (MIPS) as the main indicator. The material footprint indicator considers not only the economically used but also the not economically used abiotic and biotic resource flows (unused extraction) as they also implicate environmental impacts. Generally, all environmental impacts are reduced by 2050 compared to today except the land occupation.

Viebahn explained that the additional energy demand caused by producing insulation materials is overcompensated by considerable energy savings during building operation. They identified no trade-offs. The contribution of the production of insulation materials to the total environmental impacts is low compared to that of space heating using fossil fuels. Viebahn summarized that at the moment there is no harmonization of LCA impact assessment methods and the use of the MIPS indicator and hence more research related to resource impact indicators is necessary. He also stated that the implementation of the MIPS method in LCA databases, such as ecoinvent, is complex and time consuming. Furthermore, the HEAT model should be extended by various types of settlements as well as more life cycle stages of the buildings (demolition and recycling in particular). The focus of scenario modelling often lies on emissions and should be extended by resource efficiency analyses.

4 LCA and technology assessment

The afternoon session was opened by Axel Kölling (ERK) who presented a case study about technology-specific LCA contributing to an energy strategy. He showed how a fire-tube boiler (natural gas operated) was analysed and improved based on an LCA study and on a cost comparison method. The results of this study are used as a measure of improving the sustainability of the product.

Benoit Verzal (Quantis) elaborated an environmental assessment of hydrogen (H_2)-based mobility. The study is being conducted to raise awareness of life cycle thinking and mobilising the hydrogen sector as well as to guide public funding decisions on H_2 production and use options in mobility. Furthermore, the most environmentally relevant life stages and process were identified. The functional units used in the analysis are 1 km travelled with an H_2 vehicle (passenger car, vehicle type Golf A4) and 1 kg of H_2 at the

factory gate at 30 bar. They analysed four different scenarios for H_2 production. In the study, the environmental impact assessment method ILCD is chosen. The infrastructure as well as the H_2 production is the main drivers regarding climate change impacts (preliminary results). The technology where natural gas is used to form H_2 produces the largest amounts of greenhouse gas emissions both in a cradle to wheel and a cradle to gate perspective. The H_2 production leads to high emissions. In contrast, the conventional diesel vehicles emit the largest share of greenhouse gases in the use phase. The H_2 cars have no emissions in the use phase and they produce fewer emissions in a full life cycle perspective. The electric car and the H_2 car produce comparable amounts of greenhouse gas emissions (modelled with the French electricity mix, which includes more than three quarter of nuclear power).

Verzal summarized that the H_2 production phase and the infrastructure (vehicle, road and construction) cause the main climate change impacts. He raised the question of how to best transform an attributional LCA approach into a consequential one.

Katrhin Volkart (PSI) presented the results of an LCA on carbon capture and storage (CCS) and whether or not it would be an option for Switzerland. According to her figures, about 22 % of CCS is needed to achieve the Swiss reduction target 2050 of greenhouse gas emissions. One scenario of the energy strategy 2050 of the Swiss Federal Council covers the future electricity demand with electricity from fossil fuels (natural gas). These plants could be equipped with CCS technologies. CCS is seen by PSI as one of the key technologies to reduce CO_2 emissions. The CCS chain covers CO_2 sources, CO_2 capture, CO_2 transport and CO_2 storage. In Switzerland, main CO_2 sources are cement plants and municipal waste incinerators. Volkart listed onshore and offshore solutions for CO_2 storage such as saline aquifers and depleted gas fields. The most suitable region for CO_2 storage in Switzerland is the Swiss midlands. The most feasible CCS option in a Swiss context is the CO_2 post-combustion capture, the transport in pipelines and its storage in saline aquifers. She presented that the global warming potential in a natural gas power plant can be reduced by more than two third by implementing CCS (reference year 2025). On the other hand, the ReCiPe method showed an increase in all indicators except climate change and photochemical oxidant formation. This results from the additional fuel which has to be burned to compensate the efficiency losses in the power plant. Hence, upstream impacts become higher with CCS. In a cement plant, the implementation of CCS could reduce climate change impacts by 75 to 80 %. However, all other environmental impacts considered will increase when installing CCS in cement plants.

Volkart concluded that CCS has a large potential to reduce greenhouse gas emissions from natural gas electricity generation (by ~70 %) and cement production (by ~40–80 %). However, trade-offs related to other environmental aspects have to be kept in mind. Regarding Switzerland, she stated that future developments may lead to the need for CCS. CO_2 capture and transport are proven technologies, but CO_2 storage is subject to considerable uncertainties. To prove the feasibility of CCS in Switzerland, a full-scale pilot project including an injection site is required. Volkart showed a CCS technology roadmap for Switzerland. It starts with settling legal aspects regarding the storage site, safety of injection and storage and the public and political acceptance first.

Rolf Frischknecht (treeze) presented selected results of and insights from the large European research project New Energy Externalities Development for Sustainability (NEEDS). He explained the interdisciplinary setting of the project and its workflow involving energy modelling, external costs and LCA experts. He summarized the different upcoming technologies for electricity production for which LCA data were collected such as advanced fossil-fuelled power, offshore wind power, photovoltaics and others. LCAs of key materials such as metals, mineral building materials, as well as transports and the European electricity mix were modified too to reflect possible future situations.

The variety of possible future situations regarding electricity mix and technology developments were captured with three scenarios: ‘business as usual’, where the potentials of technology developments are assessed pessimistically. In the scenario ‘CO_2 cap at 440 ppm’, the potentials of technology developments are based on a realistic–optimistic position, and in scenario ‘renewables and energy efficiency’, the potentials of technology developments are quantified in a very optimistic manner. The project relied on ecoinvent data v1.3, which allowed for an adjustment of the data on a unit process level. Hence, seven different sets of consistent life cycle inventory data were generated (today and three scenarios each for 2025 and 2050). Frischknecht presented the cumulative results of the emission of selected pollutants and the consumption of selected resources, covering the today's situation and four future situations (440 ppm CO_2 cap, in 2025 realistic–optimistic/440 ppm CO_2 cap in 2050, realistic optimistic/renewable in 2050, very optimistic/business as usual in 2050, pessimistic).

He concluded that the improvement potential ranges from 20 to 90 % until 2050. In some cases however, emissions may increase after 2025 because for instance the most economic sites for off shore wind parks are exploited and sites more distant from the shore will be used. The operation intense systems have lower improvement potentials, unless end-of-pipe technologies such as CCS are installed. The future development in the European electricity mix has a large influence on the results. Frischknecht summarized that life cycle thinking in energy policy is indispensable. However, future technology and policy developments should be considered when assessing future situations.

Basic LCI data for life cycle thinking in energy strategies updated electricity datasets as published in ecoinvent data version 3 were presented by Katrin Treyer (PSI). Ecoinvent data version 3.0 electricity mixes will cover 18 more countries (83 % of the worldwide electricity production), compared to ecoinvent version 2.0, with data which were compiled by Itten et al. (2012). The LCI of power plant technologies are country specific but that the fuel supply chains are not (to the same extent). Treyer showed preliminary results of the greenhouse gas emissions per kilowatt hour and their range of all technologies used in all countries covered. Furthermore, she showed the differences between ecoinvent data version 2.2 and version 3.0 regarding climate change impacts of the electricity mixes delivered to the plug (low voltage level). The kilowatt hour electricity of most countries as modelled within ecoinvent data v3.0 causes lower greenhouse gas emissions than with version 2.2.

She concluded that the new ecoinvent data version 3.0 provides higher geographical coverage of the electricity production and that country- and region-specific inventory data are of importance. The new modelling approach leads to differences in the results between versions 2.2 and 3.0 but Treyer said that these differences are explicable. She emphasised that further power plant technologies such as wave power, solar–thermal power, etc., and more geographical areas should be covered in the future and that the production volumes should be updated on a regular, annual basis.

Franziska Wyss (treeze) presented LCA of future electricity mixes according to the Swiss energy strategy 2050. For each of the three main scenarios in the energy strategy 2050, the domestic electricity production and the electricity mix including electricity trade are assessed. The mix and the power plant technologies contributing to the mix of traded electricity are modelled according to the scenarios in the NEEDS project. The environmental impact category indicators addressed are climate change, cumulative energy demand (non-renewable and renewable) and total environmental impacts (quantified with the ecological scarcity method 2006). The electricity mix of the scenario 'business as usual' causes the highest greenhouse gas emissions per kilowatt hour and the electricity mix of the scenario 'political measures' causes the lowest. The electricity mix including trade causes higher CO_2 emissions and environmental impacts per kilowatt hour than the electricity mixes including domestic production only. The present Swiss electricity supply mix causes higher greenhouse gas emissions per kilowatt hour than the 2050 electricity mixes of the scenarios 'political measures' and 'new energy policies', but they are lower compared to the electricity mix of the scenario 'business as usual'. The electricity mix of the scenario 'new energy policies' causes the fewest environmental impacts (quantified with the ecological scarcity method) whereas the electricity mix of the scenario 'business as usual' causes the highest. The present Swiss electricity supply mix, including electricity from nuclear power, causes much higher environmental impacts as compared to the 2050 mixes of all scenarios. The same is true for cumulative energy demand although the differences are less distinct.

Wyss concluded that the phase out of nuclear energy sources leads to comparatively low specific environmental impacts (per kilowatt hour). Electricity trade on the other hand may well lead to higher specific greenhouse gas emissions and higher specific environmental impacts, unless the traded electricity is mainly sourced from renewable energy.

5 Discussion and conclusions

The plenary discussion was moderated by Lukas Gutzwiller (BFE). First, the question was raised which future technologies are most important regarding LCA. One option is given by storage technologies for natural gas, which meets the stochastic nature of electricity production from renewables (wind, photovoltaics). Furthermore, it is considered worthwhile to check the so-called zero carbon technologies (for example vacuum insulation for buildings) and other innovative technologies. A further suggestion was to perform an LCA on smart grids, as the infrastructure in Switzerland was considered being old.

It was also discussed whether economic aspects such as rebound effects can be taken into account in consequential LCA and in which direction the consequential LCA should be developed. The audience argued that the usage of a consequential approach should be considered case by case and if it leaves the LCA with more information to the overall results. It was mentioned that the LCA community is very focused on physical system properties and that the economics of the technologies are ignored. The global market importance of technologies should also be taken into account.

The event showed that environmental LCA still plays a surprisingly small role in national or regional long-term (energy) policies. There are currently only few cases, where environmental life cycle thinking forms a basis in directives, laws and policies. There is still a long way to go to implement environmental life cycle thinking as a mandatory element of public policy making. In the meantime, LCA can be used to influence the political agenda by highlighting the environmental consequences of selected upcoming technologies, products or activities.